MOVES
Overview, Status and Plans

Briefing for California Stakeholders
March 27, 2006

EPA Office of Transportation & Air Quality

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Outline

- **Background & Overview**
- **Technical approaches**
  - Modal Binning
  - Fleet Characterization
- **Specific use cases**
- **Model Demonstration**

Background & Overview

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What Is MOVES?

- **MOtor Vehicle Emission Simulator**
- **New software framework intended to**
  - Replace MOBILE & NONROAD
  - Expand Capabilities
    - Additional Sources
      - Aircraft, Commercial Marine, Locomotive
    - Additional Pollutants
      - Greenhouse Gases
    - Additional Scope
      - Life Cycle Analysis

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MOVES On The Web

- **Draft MOVES2004 model and documentation can be downloaded from MOVES website**
  - www.epa.gov/otaq/models/ngm.htm
- **Email Listserver:**
  - EPA-MOBILENEWS
- **Email Address:**
  - mobile@epa.gov

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Key Changes from MOBILE

- **Inventory estimation**
  - MOBILE estimates emission factors (grams/mile)
- **Designed for analysis at multiple scales**
- **Emission rates on modal basis**
  - MOBILE rates based on aggregate driving cycles
- **Software framework**
  - Relational database structure
  - Graphical User Interface (GUI)
  - Allows multiple-computer processing if desired
- **Well-to-Wheel (aka Life Cycle) analysis**

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Planned MOVES Versions

- **MOVES2004 released**
  - On-road Energy Consumption, GHGs, Life Cycle Analysis
- **MOVES2006**
  - Adds on-road HC, CO, NOx and PM
- **MOVES2007**
  - Adds on-road Toxics, NH_3, SO_2
  - Final MOBILE6.2 replacement
- **MOVES2008**
  - Draft off-road (NONROAD, Aircraft, Com Marine, Locomotive)
- **MOVES2009**
  - Final off-road

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Key National Research Council Recommendations (May 2000)

- **Develop finer scale modeling capability**
  - Suggested “toolkit” approach for addressing multiple scales
- **Improve emission characterization**
  - In-use emissions
  - High emitters
  - Heavy-duty and off-road
  - PM and toxics
- **Improve model science**
  - Perform validation
  - Quantify uncertainty
- **Update the model more frequently**

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MOVES Design Objectives

- **Flexibility**
  - Inclusion of data from diverse sources
  - Built for local customization, even for fundamental inputs such as road types, vehicle classes, and driving patterns
- **Modularity**
  - Easy to update with new data
  - Can add new components and features over time
- **State-Of-The-Art Software**
  - Modern programming language
  - Single or multiple computer processing
- **Ease of Use**

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Quality Measures

- **Routine Model Validation**
  - MOVES2004: compare with fuel sales (< 5% nationally)
  - MOVES2006 and later: compare with independent datasets, tunnel studies, ambient ratios
- **Uncertainty Estimation**
  - MOVES2006 will include Monte Carlo simulation
  - Uncertainties of emission rates populated initially; placeholders for fleet and activity uncertainties as well
- **Peer Review**
  - Paid review via EPA guidelines
  - FACA Modeling Workgroup
  - Stakeholder and public review
  - Technical articles and conference presentations

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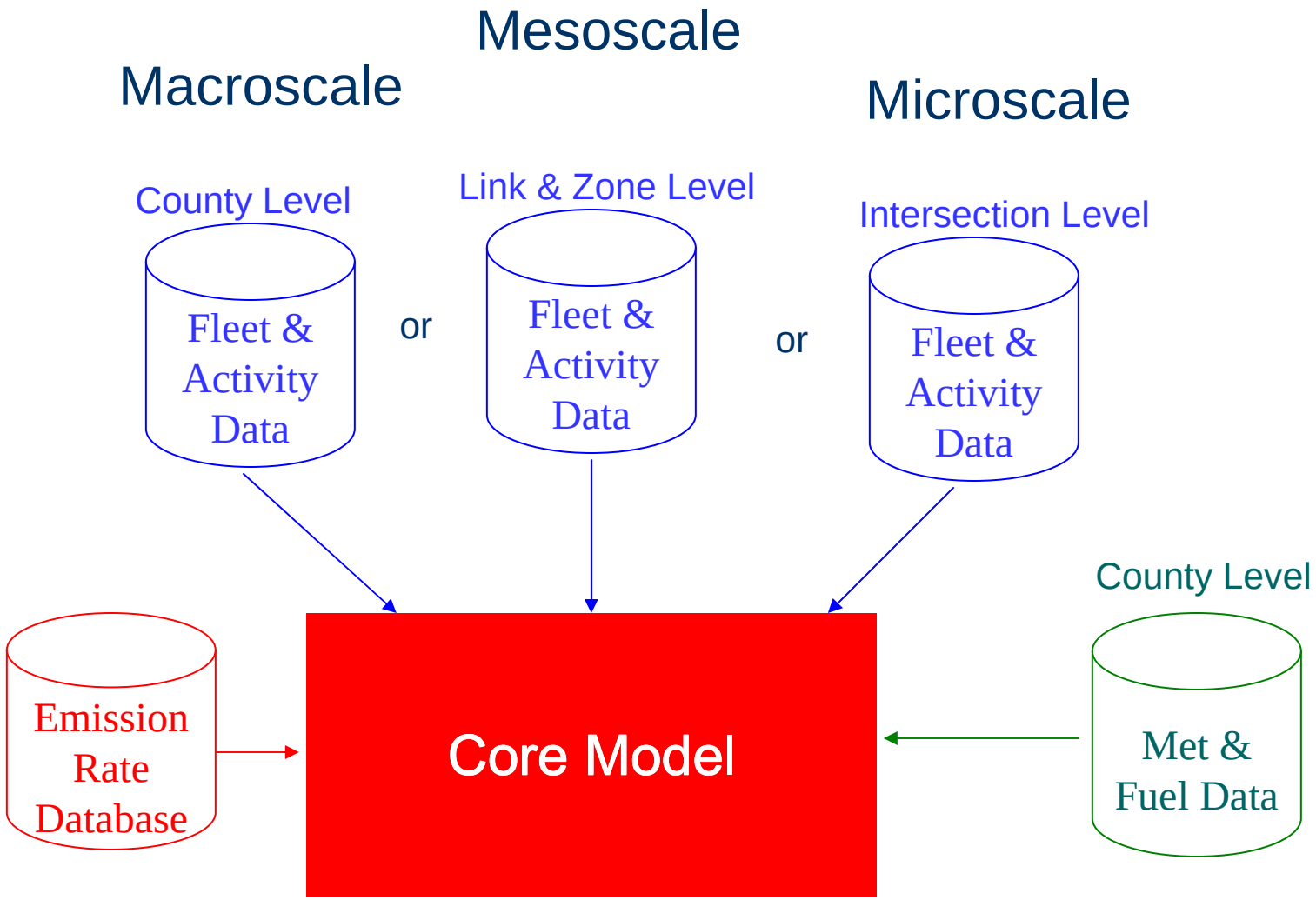
Multi-Scale Design

- **MOVES will allow multiple scale analysis**
  - **Macroscale:** aggregate national/regional inventories
    - Aggregate activity data (e.g., HPMS VMT)
  - **Mesoscale:** more detailed regional inventories
    - Link and zone-level activity data (e.g., 4-step travel demand model)
  - **Microscale:** intersection or “hot spot” analysis
    - Detailed activity data (e.g., microscopic transportation model)
- **Common set of emission rates**
- **Level of activity data needed depends on scale**
  - **Macroscale:** default data available for all inputs
  - **Mesoscale and microscale:** user required to supply activity


Mesoscale
Macroscale
Microscale
County Level
Link & Zone Level
Intersection Level
Fleet & Activity Data
or
Fleet & Activity Data
or
Fleet & Activity Data
County Level
Emission Rate Database
Core Model
Met & Fuel Data

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Mesoscale and Microscale Plans

- **MOVES2006**
  - Link-level look-up table output option
  - Microscale modeling by supplying “core model” inputs directly
- **MOVES2007**
  - DOT has funded a contractor to work with us on transportation model integration issues
  - Mesoscale activity generator and/or tools to interface with selected travel models

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On-Road Emission Processes

- **Running**
- **Start**
- **Extended Idle (“hotelling”)**
- **Evaporative Processes**
  - Permeation, Vapor Venting, Leaks, Non-Fuel Evap, Refueling
- **Crankcase**
- **Tire Wear**
- **Brake Wear**
- **Life Cycle Processes**
  - Well-To-Pump, Manufacture and Disposal (placeholder)

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Modal Modeling Approach

- **Basis of MOBILE models is average speed**
  - Appropriate for larger modeling domains
  - Aggregate approach “averages out”
  - Does not separate out differences in acceleration
- **Transportation community has pushed for approach which accounts for speed and acceleration**
  - Intersection modeling
  - Hot-spot analysis
  - More sophisticated travel models

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Start Emissions

- **More aggregate approach**
  - Current data doesn't support modal approach for starts
- **Start rates = "incremental emissions per start"**
  - Activity is the number of starts by time and place; mesoscale and microscale provide finer resolution of this
- **Soak time bins defined as operating modes**
  - < 6 min, 6-30, 30-60, 60-90, 90-120, 120-360, 360-720, >720
- **Soak distribution calculated within model from instrumented vehicle data (SampleVehicleTrip)**

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Evaporative Emissions

- **Redefined evaporative processes**
  - Permeation, Vapor Venting, Leaks, Non-Fuel Evap, Refueling
  - Allows more direct estimation of EtOH and RVP effects
- **Design allows better allocation of evaporative emissions by space and time**
  - Evaporative emissions no longer coupled to miles traveled
- **Real-world fuel temperature patterns estimated within model based on instrumented vehicle data**
- **Will use data from CRC and compliance programs**
  - New testing: Defining shape of EtOH curve, CRC E-77 (aged enhanced vehicles, “off-cycle” diurnal)

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Inspection/Maintenance

- **Single set of "With IM" emission rates**
  - Model Year ≥ 1996
    - OBD-based program
    - Gas Cap Check MY 96-99
  - Model Year ≤ 1995
    - Enhanced IM240
    - Gas Cap Check and/or Pressure Test
- **IM adjustment fraction**
  - accounts for program effectiveness, etc
- **Program options**
  - Vehicle and model year coverage, test frequency (annual, biennial, continuous)

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Future Projections

- **Emission Rates**
  - "Future Emission Rate Creator" within MOVES develops future rates based on user-supplied ratios to current technology
  - Users can customize (e.g. unique California input possible)
- **Advanced Technologies**
  - Users can customize ratios and add new technologies
  - Penetration rates can be specified through Alternative Vehicle & Fuel Control Strategy GUI
- **Fleet & Activity**
  - Users can vary VMT growth and future fleet makeup
  - All activity and fleet inputs could be customized to a calendar year of interest

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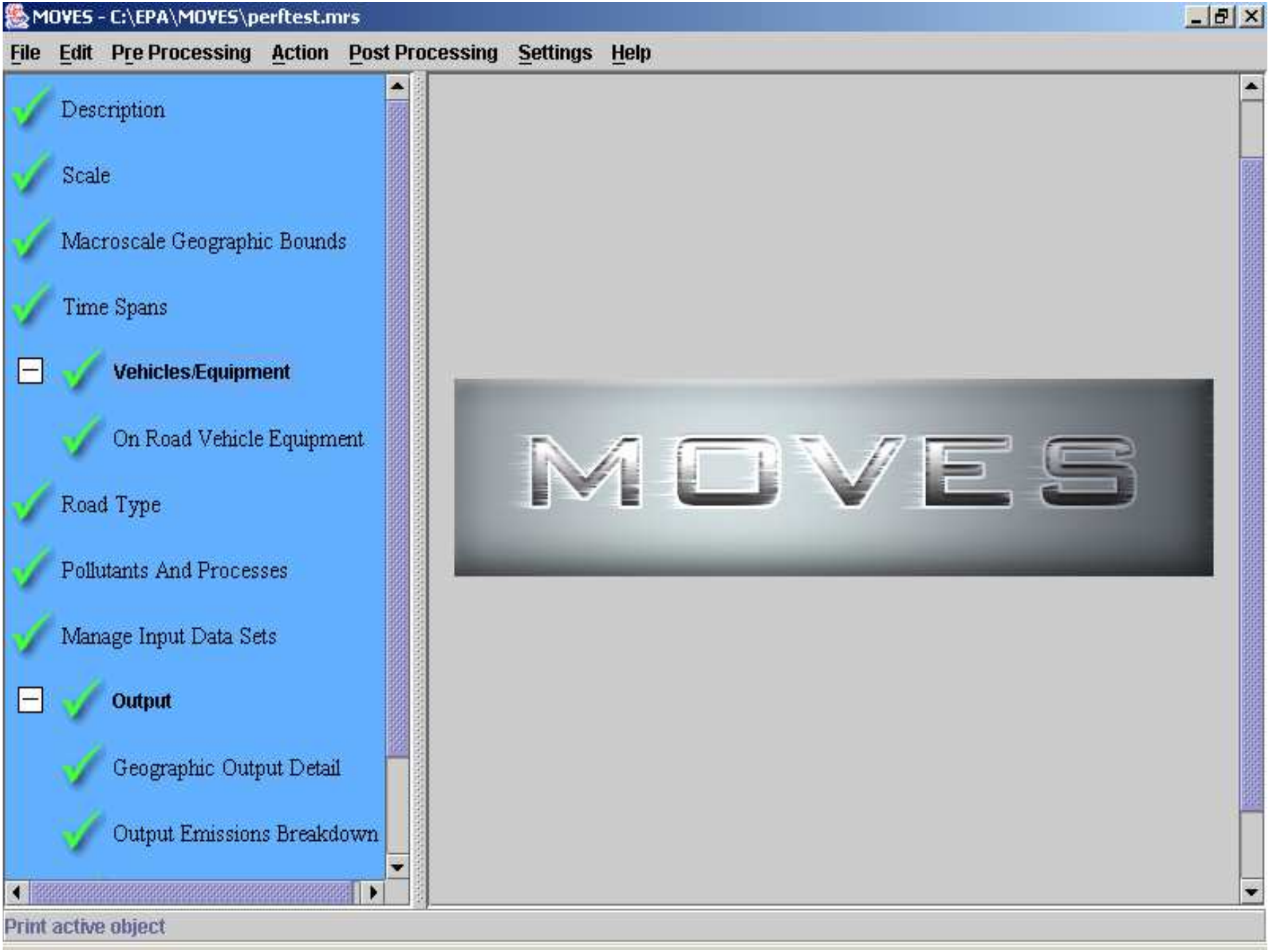
MOVES Software Framework

- **Language: Java™**
- **Fleet, activity, emission rate data stored in relational database**
  - Open-source relational database system (MySQL™)
  - Enables modularity, easy updates with new data
- **Graphical user interface or batch mode**
- **Designed for single or multiple-computer processing**
- **Output reporting and visualization**


MOVES - C:\EPA\MOVES\perftest.mrs
File
Edit
Pre Processing
Action
Post Processing
Settings
Help
Description
Scale
Macroscale Geographic Bounds
Time Spans
Vehicles/Equipment
On Road Vehicle Equipment
Road Type
Pollutants And Processes
Manage Input Data Sets
Output
Geographic Output Detail
Output Emissions Breakdown
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Print active object

Technical Focus:
Modal Binning Approach

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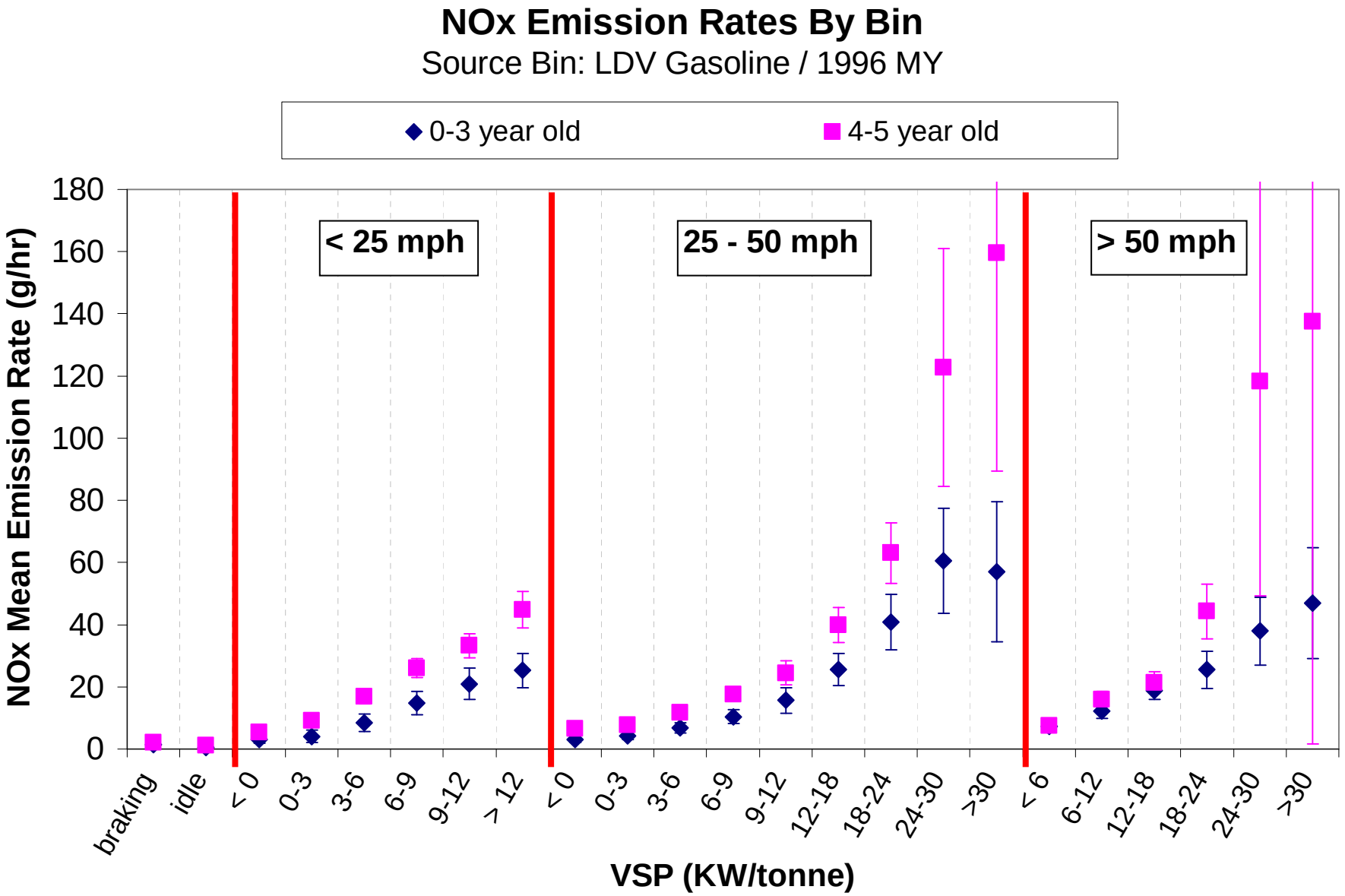
Modal "Binning"

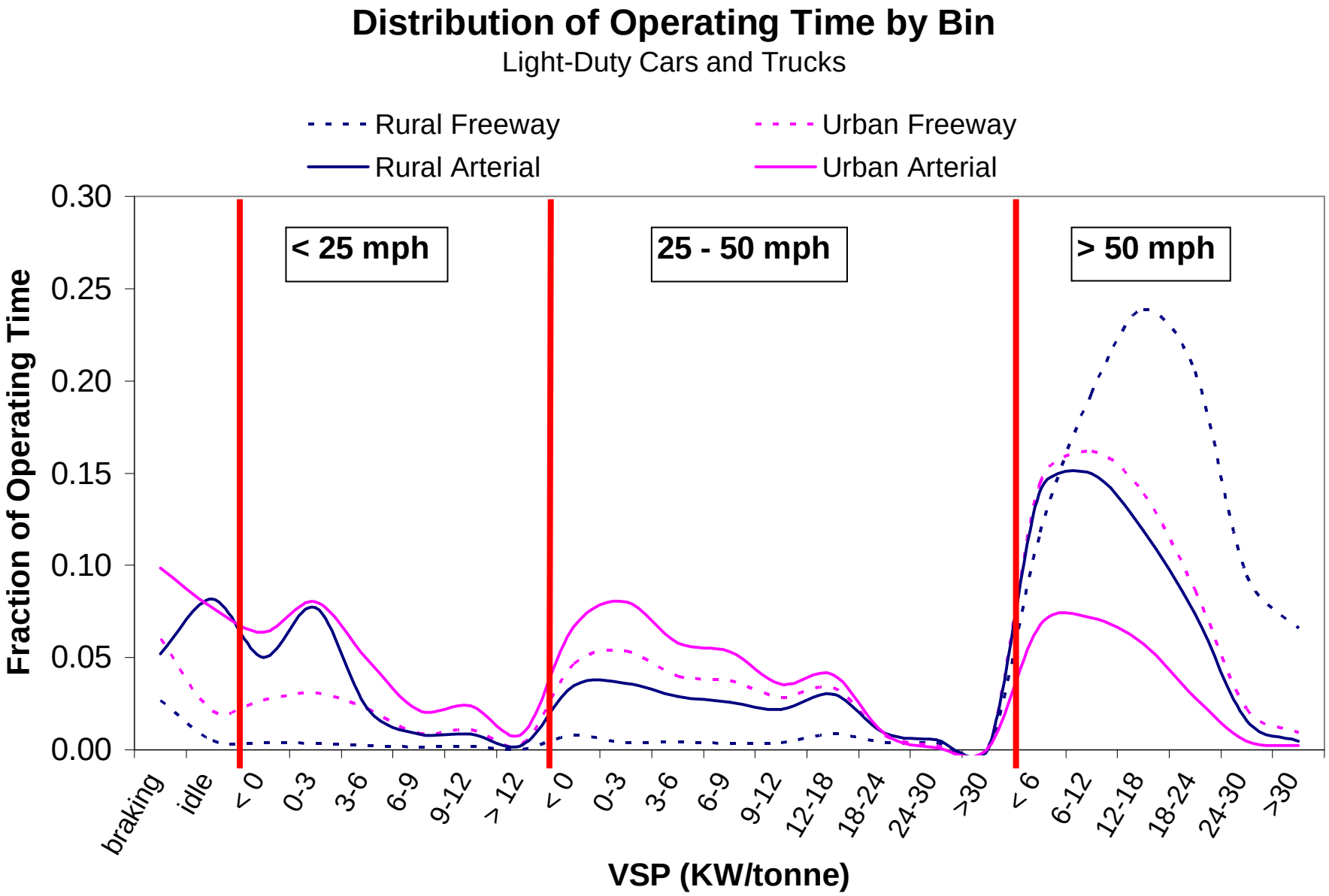
- **Group activity and emissions into "bins"**
  - Vehicle Specific Power (VSP) & Speed
    - Accounts for speed, acceleration, grade, road load
- **Any driving pattern can be modeled based on distribution of time spent in bins**
  - Adds major flexibility compared to MOBILE
- **Provides common emission rates for all scales**

MOVES2006 VSP / Speed Bins

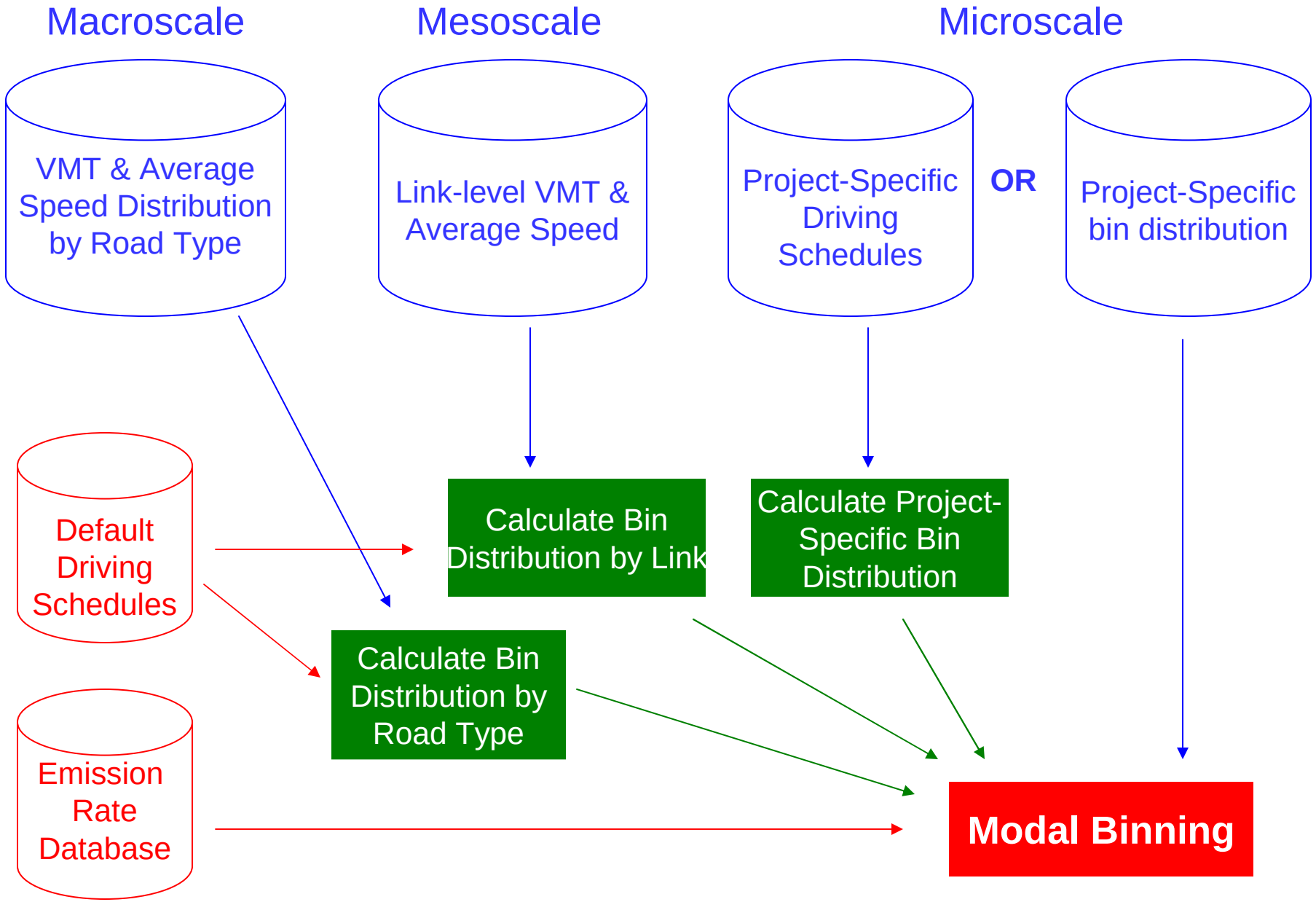
VSP	Speed Class		
	1-25	*25-50*	*50 +*
30 +	16	30	40
27-30		29	39
24-27			
21-24		28	38
18-21			
15-18		27	37
12-15			
9-12	15	25	35
6-9	14	24	
3-6	13	23	33
0-3	12	22	
< 0	11	21	

VSP Class


NOx Emission Rates By Bin
Source Bin: LDV Gasoline / 1996 MY
0-3 year old
4-5 year old
NOx Mean Emission Rate (g/hr)
180
160
140
120
100
80
60
40
20
0
< 25 mph
25 - 50 mph
> 50 mph
braking
idle
< 0
0-3
3-6
6-9
9-12
> 12
< 0
0-3
3-6
6-9
9-12
12-18
18-24
24-30
>30
< 6
6-12
12-18
18-24
24-30
>30
VSP (KW/tonne)


Distribution of Operating Time by Bin
Light-Duty Cars and Trucks
Rural Freeway
Urban Freeway
Rural Arterial
Urban Arterial
Fraction of Operating Time
0.30
0.25
0.20
0.15
0.10
0.05
0.00
< 25 mph
25 - 50 mph
> 50 mph
braking
idle
< 0
0-3
3-6
6-9
9-12
> 12
< 0
0-3
3-6
6-9
9-12
12-18
18-24
24-30
>30
< 6
6-12
12-18
18-24
24-30
>30
VSP (KW/tonne)

Applying Modal Binning at Different Scales



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Speed and Drive Schedules

- **Average Speed Distributions**
  - By hour, day and roadway type
  - Urban distributions from study of travel models in several cities
  - Rural distributions from Sierra chase car work in California
- **Driving Schedules**
  - By source types, roadway type & average speeds
  - Defaults
    - New MHDV and HHDV schedules developed by ERG based on heavy-duty driving surveys in California
    - MOBILE6 facility cycles used for LD, with new high-speed schedules
    - WVU cycles for urban bus and refuse trucks

Technical Approach
Fleet Characterization

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Characterizing the Fleet

- **Current difference in how activity and emission data sources characterize vehicles**
  - e.g., HPMS VMT Classes & EPA Certification Classes
  - MOBILE guidance includes external HPMS/EPA mapping
- **MOVES integrates activity and emission data**
  - Source Types
    - defined by unique activity patterns, based on HPMS classes
  - Source Bins
    - defined by unique emission characteristics
  - MOVES maps between the two classification schemes by model year

MOVES Source Types

HPMS Vehicle Type	MOVES Source Type
Motorcycle	Motorcycle
Passenger Car	Passenger Car
Other 4-tire, 2 axle	Passenger Truck Light Commercial Truck
Buses	Intercity Bus Transit Bus School Bus
Single Unit Trucks	Refuse Trucks Short-haul Single Unit Long-haul Single Unit Motorhomes
Combination Trucks	Short-haul Combination Long-haul Combination

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Source Bins

- **Discriminators by "Pollutant"**
  - Energy
    - Fuel Type, Engine Technology, Model Year Group, Loaded Weight, Engine Size
  - CH_4 and N_20
    - Fuel Type, Engine Technology, Model Year Group, Regulatory Class
  - HC, CO, NOx & PM
    - Fuel Type, Engine Technology, Model Year Group, Regulatory Class

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National Default Data Sources

- **R.L. Polk for registration data, esp. for light duty**
- **VIUS1997 for truck populations and activity**
  - Will update with VIUS2002 for MOVES2007
- **FHWA for VMT and registration data**
- **Specialized sources**
  - Federal Transit Administration
  - Recreational Vehicle Industry Association
  - Motorcycle Industry Council
  - School Bus Fleet Magazine
  - Others (documented in “Highway Population and Activity Data for MOVES”)

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Updates for MOVES2006

- **1990 Base Year estimates**
  - Model will estimate years 1990, 1999-2050
- **Update sales & VMT growth**
  - Annual Energy Outlook
- **Add activity components related to start and evaporative emissions**
  - Instrumented vehicle trip patterns

Addressing Specific Use Cases

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Regulatory Development

- **Ability to reflect new data during development process** 🕒 **database scheme allows updates of fleet or emission data, including the development of numerous alternative datasets for regulatory "what-if" cases**

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Regulatory Development, cont.

- Precisely quantify future emission changes due to potential standards for exhaust and evaporative emissions, anticipated new or retrofit technologies, fuel changes, operational restrictions, Smog Check etc. 🕓 all of these programs can be addressed in MOVES, either directly via control strategies, or through the development of alternative databases

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State Implementation Plans

- Reflect California's vehicle/equipment fleet (in all operating modes over lifetime of engines), climate conditions, and mobile source control programs
  🕓 Yes, although custom databases may be necessary to reflect non-routine scenarios
- Incorporate travel activity data (VMT and speeds) from transportation agencies 🕓 Yes
- Incorporate sector specific activity data for off-road equipment, ships, locomotives, etc 🕓 Planned for 2008

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State Implementation Plans, cont.

- Interface with air quality models (4km^2 spatial resolution, day specific conditions) 🕓 **Gridded output will be possible**
- Estimate benefits of new control measure concepts for old, current, or future vehicles/equipment in any year 🕓 **Possible through control strategies or alternative databases**

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Transportation Conformity

- Use link-based travel demand model output to project on-road emission impacts of a single transportation project and comprehensive transportation plans at least 30 years into the future 🕓 Yes; MOVES2006 will product link-level emission factors to couple with link-level transportation. Future versions will work with direct input from travel models.

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Community Health Assessments

- **Project microscale emissions with high spatial/temporal resolution including county specific vehicle fleet/operations and support ultimate transition to GIS based emission systems**
  - **Microscale modeling possible; spatial/temporal resolution will depend on user input. MOVES is not a GIS-based model but could support GIS analysis**

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Statewide Emission Inventories

- **Statewide emission inventories and trends for all years, seasons, months 🕓 Yes; years other than 1990 and 1999-2050 will require additional input**

Some Options for Implementation

- **Software implementation**
  - Default framework w/ California inputs
    - Would mean using default activity approach, e.g., facility-based
  - California-specific implementation w/ MOVES Core Model
    - Could implement alternate activity framework, e.g., trip-based
- **Data customization**
  - California-specific fleet & activity only
    - Common emission rate database
  - California-specific fleet, activity, and emissions
    - MOVES software framework only commonality w/ Fed model
- **Could customize inputs to reflect California-specific programs (e.g., LEV II) with any approach**

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County-Specific Inputs and the NEI

- **MOVES database will be modified to accommodate county-specific inputs, e.g. VMT, speed distribution, registration distribution**
- **MOVES database will function as repository for National Emission Inventory input data**
  - States will submit data directly into database
  - EPA is currently moving toward this process with NMIM

Summary

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Summary

- MOVES was developed to address NRC recommendations and the evolving needs of the user community
- MOVES2004 released; development of initial on-road criteria pollutant version well underway
- MOVES framework could be adapted to meet California's modeling needs